

A combustion system

5 The present invention relates to a combustion system for generating a hot gas, and in particular to a premix burner connected to a combustion chamber.

Many premix burners rely on swirling to produce efficient  
10 mixing of reactants. However, interaction between the complex flow patterns within the swirling fluid and acoustic resonant modes in the combustion chamber can lead to undesired thermoacoustic pulsations or vibrations. These pulsations are associated with coherent vortical  
15 flows in the combustion chamber. The vortical flows introduce periodicity into the mixing process, which may lead to periodic heat release and resonant coupling with the combustor acoustic resonant modes. Vortical mixing of the reactants also tends to be limited to large scale  
20 mixing with the result that mixing in regions between vortices in the vortical flow tends to be poor.

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Thermoacoustic vibrations are problematic in combustion processes, since they can lead to high-amplitude pressure  
25 fluctuations, as well as to a limitation in the operating range of the burner in question and to increased emissions from the burner. Many combustion chambers do not possess adequate acoustic damping to account for such thermoacoustic vibrations.

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In conventional combustion chambers, the cooling air flowing into the combustion chamber acts to dampen noise

and therefore contributes to the damping of thermoacoustic vibrations. However, in modern gas turbines, an increasing proportion of the cooling air is passed through the burner itself in order to achieve low emissions. The cooling air  
5 flow within the combustion chamber is thus reduced, resulting in reduced damping of the thermoacoustic vibrations in the chamber.

Another method of damping is the coupling of Helmholtz  
10 dampers in the combustion chamber, preferably in the region of the combustion chamber dome or in the region of the cold air supply. However, such dampers require a considerable amount of space in order to allow them to be accommodated in the combustion chamber. Since modern combustion  
15 chambers tend to be relatively compact, it is usually impossible to incorporate Helmholtz dampers in the combustion chamber without substantial re-design of the chamber.

20 A further method of controlling thermoacoustic vibrations involves active acoustic excitation. In this process, a shear layer which forms in the outlet region of the burner is acoustically excited. A suitable phase lag between the thermoacoustic vibrations and the excitation vibrations  
25 makes it possible to achieve damping of the combustion chamber due to the superimposition of the vibrations and the excitation. However, a considerable amount of energy is expended in generating such acoustic excitation.

30 A further means of providing damping in the combustion chamber is to modulate the fuel mass flow in the burner. Fuel is injected into the burner with a phase shift relative to measured signals in the combustion chamber so

that additional heat is released at a minimum pressure .  
This reduces the amplitude of the thermoacoustic  
vibrations. However, this technique also leads to high  
emissions due to the increased fuel.

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A further alternative is to inject air into the burner via  
nozzles to disturb and break up the vortical flow. However,  
the required additional pipes and plumbing complicates the  
design of the combustor. Furthermore, the required  
10 additional air flow reduces the overall efficiency.

In a similar technique, the vortical flow is broken up by  
baffles which are located inside the burner in order to  
disturb the vortical flow. However, the inclusion of such  
15 baffles increases the constructional outlay of the burner,  
which is disadvantageous.

An object of the present invention is to provide a  
combustion system in which the above disadvantages are  
20 overcome.

The invention provides a combustion system for a heat  
generator, comprising a premix burner and a combustion  
chamber, the premix burner being connected to the  
25 combustion chamber by means of an outlet, wherein the  
outlet comprises a multiply stepped transitional structure  
in the direction of flow of fluid so as to create  
turbulence in the fluid flow.

30 In contrast to the sharp-edged transition between the  
premix burner and the combustion chamber the combustion  
system designed according to the invention has a gradual  
transition between the premix burner and the combustion

chamber, said transition having a segmented line-up of rectilinearly designed side wall portions forming a multiply stepped transitional structure. The term "multiply stepped transition" is intended to mean basically any transitional geometry which widens in steps the flow cross section within the premix burner, which is dimensioned smaller than that within the combustion chamber, successively to the combustion chamber cross section.

- 10 In a preferred embodiment of the invention, the transitional structure comprises three to five steps, and preferably four.

By a gradual transition being provided between the premix burner and the combustion chamber, the widening of the fuel/air mixture entering the combustion chamber is increased considerably, the result of this being, even in the case of a gradual transition, that a marginal flow having cross vortices is formed, which, however, impinges onto the combustion chamber wall at a reapplication point which is very much nearer in the direction of the premix burner than in the case of a sharp-stepped transition. This has an advantageous effect on the combustion process in two respects. Thus, on the one hand, the marginal flow having cross vortices is reduced, and therefore the intensity and number of the cross vortices formed are also reduced, with the result that the combustion chamber pulsation generated by thermoacoustic vibrations can be decisively damped. On the other hand, by virtue of the markedly greater widening of the fuel/air mixture propagated within the combustion chamber, the dead space caused by shading-off effects is reduced to a minimum, with the result that virtually the entire combustion chamber volume is available for the

combustion of the fuel/air mixture and ensures complete combustion of the fuel.

The invention will now be described in detail with reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional view of a burner according to the invention attached to a combustion chamber;

Figures 2a and 2b are graphs showing the effect of the invention on pressure fluctuations.

In Figure 1, a heat generator has a burner 1 with a swirl generator 2. The swirl generator 2 generates a swirl 3 with an axial flow component facing toward a downstream burner outlet 4. Mixing takes place in an area 5 of the generator 2, so as to ensure adequate mixing of fuel and combustion air. The axial flow cross-section of the area 5 widens in the direction of the outlet 4; this configuration facilitates attainment of a constant swirl 3 in the area 5 with an increasing combustion air mass flow in the direction of the longitudinal axis B of the burner 1. The generator 2 comprises two hollow partial cones (not shown) arranged offset to one another. The offset of the respective centre axes of the partial conical bodies creates two tangential air channels 6. A combustion air flow 7 flows, with a relatively high tangential velocity component, through the two tangential channels 6 into the area 5, thus generating the swirl 3. Fuel is introduced into the burner 1 via a fuel inlet 8 in the form of a nozzle.

The burner 1 is attached to a combustion chamber 9 via an outlet 10 through which the swirl 3 passes. The swirl 3 contains vortical flow, which causes flow instabilities including thermoacoustic vibrations which result in low performance of the combustion chamber.

The outlet 10 is provided with a series of steps 11, 11a and 11b. The steps 11, 11a and 11b induce multiple inflection points into the swirl 3 as a result of the sudden change of velocity of the flow at the steps 11, 11a and 11b. Multiple sources of turbulence are thus formed. This increased turbulence serves to break up the existing vortical flow in the swirl 3, thus stabilising the flow. As a result the performance of the combustion chamber 6 is improved. Furthermore, the increased turbulence results in better small scale mixing. It should be noted, however, that emissions are not noticeably increased as a result of the increased turbulence.

The preferred range of the ratio of the length to the height of the steps 11, 11a, 11b is 1:1 - 7:1, but can be as large as 10:1. The number of steps depends on the expansion ration at the outlet 10, on the re-attachment length, and the selected length to height ratio. The number of steps is usually between three and five. However, one single step can be effective. This is particularly so, if the step height is the same as the amplitude of the dominant vortices.

Figure 2a shows the effect of the burner according to the invention on pressure fluctuations according to variation in Lambda number. Line 12 is effectively a baseline, i.e. it represents a burner which has not been modified in any

way. Line 13 represents a burner having steps 11, 11a and 11b with a length to height ratio of 1:1. Line 14 represents a nozzle with extended steps, i.e. steps extended beyond a recirculation zone. This configuration  
5 can lead, however, to a destabilisation in combustion.

Figure 2b shows the effect of the burner according to the invention on pressure fluctuations according to variation in power. Line 12a is effectively a baseline, i.e. it  
10 represents a burner which has not been modified in any way. Line 13a represents a burner having steps 11, 11a and 11b. Line 14a represents a burner with extended steps.

It will be appreciated that variations of the embodiment  
15 described above are possible. Alternative configurations of pre-mix burners are well-known to persons skilled in the art. Similarly, it would be possible to replace the conical swirl generator 2 with a cylindrical swirl generator. It is also known to arrange a displacement  
20 body, tapering towards the outlet 10, inside the swirl generator; this could provide a further alternative embodiment of the invention.

The number and depth of the steps could also be varied.